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Photograph of the A line in the Solar Spectrum.
By George Higgs.

(*Communicated by the Secretaries.*)

Where the eye begins to fail in ascending towards the more refrangible portions of the solar spectrum, the properties of the haloid salts of silver enable us to continue the thread of research, and in the opposite direction the photographic limits have from time to time been set back as our knowledge of organic chemistry has advanced, till the distinction between the chemical and thermal has ceased to exist. In spite of this, however, an examination of results seems to point to the fact that photography has been slow in adding to the information hitherto gained by eye-observation of such regions which lie on the less refrangible limits of the visible spectrum.

With a view to formulating some process for preparing dried emulsions which shall give certain and uniform results of a great degree of sensitiveness for this region I have for some time been engaged in investigating the properties, and in the preparation in a state of purity, of some of the salts of the anthracene series, an account of which I hope to furnish in its place (belonging as it does more to the domain of Chemistry than to that of Astronomy).

I herewith beg to submit to the notice of Fellows interested a copy of a portion of "Great A" from my Photographic Map of the Normal Solar Spectrum. In order to show as much detail as possible I have had to enlarge about ten diameters, or three times Ångström's scale. The "head" is seen to be composed of about 50 lines. Each line of the pairs composing the fluting or "tail" is a nebulous double. Between the pairs and commencing at w. l. 7622 are to be seen other pairs which are apparently harmonically related to the thicker nebulous pairs. The same region taken with a low Sun of about 86° to 88° zen. dis. exhibits the head as one broad band, disintegration commencing at w. l. 7595 and 7598·5.

Spectroscopic Notes and Queries. By the Rev. A. L. Cortie, S.J.

(*Communicated by E. W. Maunder.*)

I. Has D_3 a coincident dark line in the solar spectrum?

The position of this chromospheric line as given by Young in his list of bright lines is w. l. 5874·9. In some of the spectroscopic maps which I have consulted, dark lines are indicated differing by less than one-tenth metre from the position of the bright line. Ångström (1868) draws a telluric line at 5874·2, followed on the less refrangible side by a band of slight intensity terminated by a well-marked line at 5878·3. Fievez (1882),

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whose wave-lengths are based on those of Angström, draws a faint double with w. l. 5875·05 and 5874·7, lines which also appear in Piazzi Smyth's Winchester Solar Spectrum (1884). In Thollon's (1890) splendid atlas several faint lines, apparently of solar origin, are drawn near this position. It will have been remarked that one of the lines drawn by Fievez and Piazzi Smyth differs by only two-tenths of a tenth metre from the position assigned by Young to the chromospheric line. This line also appears on some wonderful photographs of this region of the solar spectrum which I have lately received through the kindness of Mr. Higgs, and which will be referred to later more in detail. The other line, drawn at 5875·05, is photographed as a double. The wave-lengths on the photographs are, of the single 5875·9, and of the double 5876·5, the standard chosen being Mr. Louis Bell's value for the wave-length of D_2, 5890·188, which exceeds by 1·21-tenth metres the number of D_2 on Angström's map. It would appear, then, from a mere examination of these maps that D_3 is exceedingly close to, if not coincident with, a dark line on the solar spectrum.

Trouvelot would make D_3 coincident with a dark line, evidently from his drawing the ray 5874·7 of Fievez, or 5875·9 of the photographs. This drawing occurs in the plate which accompanies his paper, "Sur la structure intime de l'enveloppe solaire" (Bull. Astron. 1885). He remarks: "On a quelquefois affirmé que le spectre normal du Soleil ne contient aucune raie noire correspondant à la raie brillante D_3 du spectre de la chromosphère et des protubérances . . . Ceci est une erreur des plus grandes, car cette raie existe, et, bien qu'elle soit excessivement fine et peut-être variable, il n'y a guère de jours où elle ne soit visible dans notre instrument." Further on he speaks of this line as possessing "la finesse extrême."

These observations would appear to be at variance with those of l'abbé Spée, who, in his paper "Sur la raie dite de l'Helium (Bull. de l'Académie Royale de Belgique, 2^{me} série, tome lxix., No. 5, 1880), writes as follows:—"Dans la région correspondante du spectre, il ne se trouve aucune raie obscure. Huggins, dit à la vérité, avoir vu quelquefois à cette place une légère ligne noire, indice d'un renversement partiel, mais ce phénomène n'a jamais été constaté par les spectroscopistes italiens, et le beau ciel de Rome, l'atmosphère si pure et si transparente de la Sicile, sont, pour ce genre d'observations, des garanties de succès que l'éminent physicien anglais a pu difficilement égaler." Unfortunately he gives no reference to Huggins's paper, so that the opinion of this observer, with regard to the point at issue, cannot be quoted here. But Young would seem to lean to the view that the bright line has ordinarily no corresponding absorption ray. Speaking of an observation of the reversal of D_3 as a dark shade over a sun-spot on September 22, 1870 ("The Sun," ed. 1882, p. 130), he thus writes: "It will

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be noticed that . . . . the helium-line D_3, which usually is invisible on the solar surface. . . .”

These discrepancies might be explained if the line in the solar spectrum, with which, according to Trouvelot, D_3 coincides, and which at least is extremely near to it in position, were due to the absorption exercised by our atmosphere. In passing it may be noted as an analogous case that the atmospheric double 5990·01 would also seem to be in close proximity to a bright line in Young's list. Ångström has no solar line on his map nearer to D_3 than the iron line at 5883·03, and he marks 5874·2, the line in question, as an air line. Nor has Cornu drawn any solar line in this region of the spectrum. My own observations taken at Stonyhurst with the Browning automatic spectroscope attached to the 8-inch equatoreal, and in which a dispersion of twelve prisms of 60° was employed, also point to the line being atmospheric. On March 17, 1887, it was not visible, the definition being very good, and the Sun near the meridian. The same was the case at noon on a day in June 1888, when the sky being hazy the definition was only fair. But the line was well seen at 6.15 P.M. on May 28, 1887, when the definition was excellent, twelve other lines also being observed between it and D_2. Three days later, the definition being fair and the sky hazy, these lines about D_3 were all visible at 1.45 P.M., but very much less dark than on the 28th when the Sun was low. The photographs of Mr. Higgs entirely corroborate these observations. They were taken with a Rowland concave grating of 14,438 lines to the inch, and represent the D lines and adjoining portions of the spectrum in a high, intermediate, and low Sun. In the high-sun picture, taken at 2 P.M. on August 17, 1890, the lines about D_3 are just traceable as very faint lines. About twenty lines have been photographed between D_2 and the wave-length in question. In the intermediate-sun picture, taken on September 10, 1889, at 7.30 A.M., the lines about D_3 are much darker, and the total number has increased to about thirty. In the magnificent low-sun photograph, taken on August 30, 1890, at 5.35 A.M., the lines about D_3 are quite conspicuous, being almost as dark as the iron line at 5883·03 of Ångström's map. The total number of lines is now more than fifty. These three photographs alone would lead us to conclude that the line with which D_3 is supposed to be coincident is not of solar origin. But in order to remove all possible doubt, Mr. Higgs photographed, at the end of last October, the E and W limbs of the Sun on two contiguous strips. In this photograph all the lines of solar origin are displaced owing to the Sun's rotation, the air lines remaining unaltered in position. The lines near D_3 are not displaced, being thus proved to be due to our atmosphere. The solar lines nearest to D_3 are a faint pair at 5873·5, and a faint line at 5878, the latter line being the least refrangible of a triplet of which the two other components are air lines. These last two lines are

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not visible in the high-sun photograph, and just traceable in that of the intermediate Sun. I would, in passing, allude to a few interesting details which are shown on this last photograph. Thus the strong iron line 5883·03 (Ångström) can be distinctly doubled in one strip, but is shown as a single in the other. No ordinary dispersion would ever have shown that this line is not common to iron and our atmosphere. In one strip the nickel line is widely separated from an air line slightly less refrangible, but almost coincides with it in the other. The mean of five measures made with the Hilger micrometer-microscope by Father Sidgreaves at Stonyhurst gives ·066 mm. as the value for the double displacement corresponding to a velocity for each limb of 1·4 miles per second.

With regard to the coincidence of D_3 with the dark air line as observed by Trouvelot, I would incline to the view that insufficiency of dispersion or displacements in the bright chromospheric line rendered the lines apparently coincident, but that they are really separated by a minute difference of position. The following are a few details of observations taken at Stonyhurst with regard to this point.

March 17, 1887. Time 11.15 A.M.—Definition very good. No dark line seen coincident with D_3.

May 28, 1887. Time 5.30.—Definition very good. Sky slightly hazy. D_3 appeared to be between the close double, but certainly more refrangible than the less refrangible of the pair. Observation very difficult.

Later, 6.15 P.M.—Definition excellent. D_3 certainly between the two lines, and distant by estimation two-thirds of the interval between the dark lines from the less refrangible of the pair.

June 2, 1888, time 12 P.M.—Definition fair. Sky hazy. No line seen coincident with D_3.

September 15, 1890.—D_3 very bright in a small prominence. No black line could be detected coincident with the bright line. Definition fair. Time 12.30 P.M.

September 18, 1890, time 2 P.M.—Definition good. The line at 5875·05 was much blacker and sharper than 5874·7. The latter line was extremely faint and rather fuzzy in appearance. D_3 seemed so close that I could not be absolutely certain that it was not coincident with the less refrangible side of the faint line.

Observations were taken on October 27, 1890, by Father Sidgreaves and Mr. W. McKeon, at 11.30 A.M., and again at 2.40 P.M., with both the Browning automatic and the Hilger direct-vision spectroscopes. The observations were very carefully made by each observer, and with the same result. "No trace of a dark line in perfect coincidence with D_3. Line to the left well defined (i.e. 5875·05 Fievez); to the right no line observed but a kind of hazy band, the space between, and in perfect coincidence with D_3, being intensely bright and without any dark line."

So far, then, as we are warranted by the observations discussed in the present paper, we may conclude:

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(1) That D_3 has been seen as dark in a sun-spot.

(2) That there is a faint dark line in the solar spectrum, at least within two-tenths of a tenth metre from the bright line.

(3) That this line is due to our atmosphere.

(4) That observers are disagreed as to whether the dark and bright lines coincide in position.

II. The line Ångström 6676·9.

In the memoir which accompanies the late M. Thollon's recently published exquisite maps of the solar spectrum, the author calls attention to the ray 6676·8 (·9 as it is given in Ångström's catalogue), remarking that it is an interesting fact that this line, one of the feeblest on Ångström's map, is now the strongest in the region B—C. He further identifies the line with 641 of Kirchhoff's map, states that its origin is due to iron, and says that it is often seen in the spectrum of the chromosphere and prominences. He also quotes the authority of M. Dunér in corroboration of his remarks, and reports that the latter spectroscopist considers the line variable, and as varying in intensity with the state of solar activity. I propose to examine the statements of the lamented spectroscopist, as to the identification of the line with Kirchhoff, as to its origin, its coincidence with a bright line in the chromosphere, and as to its variability.

The third point may be passed over at once, as Young gives the line in his list as having a frequency of 25, and a brilliancy of 50 (C = 100, 100), and in the maximum period of solar activity it was frequently seen bright at Stonyhurst.

The first, second, and fourth points are more doubtful. Young in his list of chromospheric lines identifies the line with K 654·3, and at Stonyhurst the line was, when first seen bright in the chromosphere, independently identified as corresponding to this number of Kirchhoff's scale. In the catalogue issued by the British Association in 1878 the corrected w. l. is given as 6677·6, and here also the line is identified with K 654·3. On Kirchhoff's map both 654·3 and 641·0 have an equal intensity and width.

Next, as to the origin of the line. Is it an iron line? In Young's list it is attributed to this element, and also as possibly coincident with a line of barium. But neither in Ångström's map, nor in the catalogues of the spectra of the metals published by the British Association, is there any iron line given in this position. But a barium line is given on the authority of Liveing and Dewar at 6677. At least K 641 is not due to iron, but on the authority of the British Association Catalogue to calcium. The nearest iron line is at 6663·1.

Lastly, as to the variability of the line with the activity of the Sun. Examining such maps and catalogues as I have had access to, the following is the result of the comparison:—Kirchhoff (1861) draws the line as one of the strongest in the region B—C, in Ångström's map (1868) it is one of the faintest. Burton (British Association Catalogue, 1878) makes it one of

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the most intense in this region; it is one of the strongest in the map of Fievez (1883), and also in all three strips of the Winchester Solar Spectrum of Piazzi Smyth (1884). Finally, Thollon (1890) draws it as the strongest in this region. It would seem, then, that further evidence is required before we can conclude that the line is really variable, for all authorities except Ångström agree in making the line a strong line.

III. The line Angström 6361·16.

In the Philosophical Transactions of the Royal Society, 1873, No. 163, Part 1, in a paper "On Spectrum-Analysis in connexion with the Spectrum of the Sun," Mr Lockyer gives a long line of zinc at w. l. 6362·5, and remarks, "This line was in the Sun in Kirchhoff's time, but has now dropped out; its number on Kirchhoff's map is 771·7." Turning to the British Association Catalogue for 1878, the observations for which were made by the late Mr. Burton, we find K 771·8 identified with w. l. 6361·41, and its origin attributed to zinc. The number 6361·41 has been obtained from the w. l. 6361·16 as given in Ångström's catalogue by applying the correction indicated at p. 29 of his memoir. Burton places the line among the faint lines of the solar spectrum, and it is also drawn as a faint line on Ångström's map. It was therefore to be seen on the Sun in 1861, 1868, and 1878. I have observed the line as widened in Sun-spots five times in 1884, and twice in 1889, and I have no evidence of my own to show that the line was not to be seen in intermediate years.

Note on the Sun-spots of 1888. By E. W. Maunder.

The sun-spots of 1888 were by no means so interesting as those of 1889, for they did not present those strong indications of reviving energy which were seen in the latter year. I have, however, thought that it might possibly be worth while to give year by year some such summary of sun-spot phenomena as I attempted in the paper I read at the April meeting of the Society; and as in this case it would be desirable to do so, not only for future years in their turn, but also for the past years of the Greenwich record, I have commenced with 1888, hoping to follow it with similar notes for the years 1882 to 1887.

Before taking the spots of 1888 I should like to make a slight addition to what I said before concerning the spots of 1889, with the view of strengthening the opinion I then expressed, that the great spot of June 16, 1889, marked the commencement of the new cycle. This may be seen most clearly by dividing the year into two portions: viz., January 1 to June 15, and June 16 to December 31. The latter portion of the year may likewise be further divided into two divisions, the first division including the spots within 10° degrees of the equator, which for the most part may be considered to represent the last efforts of